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Endovascular Treatment of Severe Symptomatic Stenosis of the Internal Carotid Artery: Early and Late Outcome

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Objectives: to report a 6 year experience with carotid percutaneous transluminal angioplasty (CPTA) in a selected group of patients.

Material and Method: we retrospectively reviewed our experience after performing 54 CPTAs, with (n=18) or without (n=36) stent deployment, over a period of 6 years from 1993 to 1999. All patients, except one, suffered from focal hemispheric neurologic symptoms. During the same time period 284 patients underwent carotid endarterectomy. The selection of the 54 patients (16%) for CPTA was based on the carotid angiogram and the sole inclusion criterion for endovascular treatment was a short, concentric, and smooth stenosis of more than 70% without ulceration or severe calcification. All patients who had a patent internal carotid artery after the last control were invited for a clinical duplex examination and all duplex examinations were carried out by a single experienced observer.

Results: early outcome (<30 days): CPTA was judged technically successful in 50 cases (93%). Ten patients (18%) experienced a neurological event in relation to the procedure and one patient (2%) suffered a major stroke. One stent occluded within 30 days. Late outcome: Forty-six patients (85%) entered the follow-up study after a median of 34 months (range 1–80 months). Six patients (13%) had recurrent symptoms. The colour-duplex examination (n=45) showed internal carotid artery occlusion in 2 patients (5%), and restenosis (>70%) in 10 patients (22%). We found no significant difference in the reoccurrence of neurological symptoms or the rate of restenosis between patients treated with and without stent (Log Rank 0.28, p=0.59). ICA was patent without restenosis in 60% after 48 months in patients treated with CPTA alone, and in 76% after 3 months in patients treated with a stent (N.S.).

Conclusion: CPTA in a selected group of patients has a mortality and major stroke rate comparable to that of carotid endarterectomy. However, the risk of transient neurological events was high, as well as the incidence of restenosis (>70%) after 3 years. We still consider CPTA an experimental procedure. The indications for this treatment must be clarified if CPTA should be an alternative to surgery with a comparable neurological complication rate.

Introduction

Stroke is one of the leading causes of death in the western world.¹ The risk of stroke relates to the presence of severe arteriosclerotic lesions in the common and internal carotid artery (ICA) and may be reduced if such lesions are removed. Currently, carotid thrombendarterectomy (CEA) is the treatment of choice in severe (>70%) symptomatic stenoses in the ICA because it reduces the risk of ipsilateral stroke by 17% after 2 years.²

Percutaneous transluminal angioplasty (PTA) with or without stent deployment is an established treatment of occlusive atherosclerotic disease in coronary,

renal, iliac, superficial femoral and popliteal arteries. During the last decade PTA has also been used to treat occlusive atherosclerotic disease in the ICA.³ This treatment was introduced in Scandinavia in 1993^{4,5} but is still not considered a routine procedure probably because reliable long-term results and well defined treatment guidelines are missing. The immediate benefits of carotid PTA (CPTA) vs CEA include short treatment duration, no need of general anaesthesia and avoidance of surgical stress as well as possible complications following surgical treatment, e.g. peripheral nerve lesions and haemorrhage. Despite the lack of clear evidence, it is assumed that the perioperative mortality and morbidity following CPTA is comparable with CEA.¹ The purpose of this retrospective investigation was to evaluate safety and efficiency of CPTA in a selected group of patients with significant (>70%) stenosis of the ICA.

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Material and Methods

During the time when this study was undertaken patients suspected of having a symptomatic ICA stenosis were referred to the Department of Neurology where they were screened by transcranial Doppler or by duplex scanning. If a symptomatic stenosis was suspected the patient was referred to angiography. During the period May 1993–October 1999 approximately 600 patients underwent angiography. The indication for surgical or endovascular treatment, was a high-grade stenosis ($>70\%$) on angiography which was found in 338 patients. The inclusion criteria for CPTA were sharply defined based exclusively on angiography: the stenosis had to be short (<1 cm), concentric, smooth, and without ulceration or severe calcification to provide optimal treatment conditions for the balloon procedure. Fifty-four ICAs were treated with CPTA in 54 (16%) patients and 284 (84%) patients underwent CEA. The indication for endovascular treatment in one case, however, was an asymptomatic 95% stenosis in the left ICA in a patient who was treated prior to coronary artery bypass surgery. Fifty-three patients had an atherosclerotic lesion and one patient had a stenosis secondary to irradiation of the neck for tonsillary cancer. Male/female ratio was 37/17 and the median age was 64 years (range 36–78). Thirty-one (57%) patients were smokers, 20 (37%) were treated with antihypertensive medication, 13 (24%) had ischaemic heart disease, 10 (19%) had intermittent claudication, 5 (9%) had diabetes mellitus and 5 (9%) were treated for hypercholesterolaemia.

All patients except one had a symptomatic severe lesion ($>70\%$) in the ICA: 11 patients suffered from amaurosis fugax (20%), 8 of which (15%) also had transitory ischaemic attacks (TIA), 13 (24%) patients had isolated TIA, and 21 (39%) patients had suffered from a minor stroke. Preoperative angiography demonstrated a stenosis greater than 90% in 40 (74%) patients and a stenosis between 71% and 89% in 14 (26%) patients. The criteria for assessment of the stenosis in the ICA were the same as used in the NASCET study.

All the patients received aspirin (ASA) (100–150 mg \times 1) or ASA and dipyridamole (200 mg \times 2) prior to angiography. All were catheterised through the femoral artery. Heparin (5000 IU) was administered intraarterially immediately prior to CPTA. The size of the PTA balloon matched the normal ICA diameter distal to the stenosis and ranged from 3–6 mm. We considered the PTA procedure technically successful if any residual stenosis was less than 50%. Thirty six (67%) lesions were treated exclusively with

PTA, while 18 (33%) also had a stent deployed. After endovascular treatment all patients were observed for 3–4 days, and continuously treated with ASA (100–150 mg/day) or ASA (100–150 mg/day) and dipyridamol (200 mg/day).

During the introduction of this new treatment stents were only used in case of residual stenosis ($>50\%$) and recoil ($n=1$), dissection or significant irregularities of the artery wall after PTA ($n=7$). After July 1998 stents were used more routinely. Three different types were used: the balloon-expandable Palmaz stent (Johnson & Johnson®) ($n=7$), the self-expandable Easy Wallstent® (Schneider) ($n=10$) and the self-expandable Multilink® stent (ACS) ($n=1$). Two lesions were treated with double stents.

Neurological events during and immediately after treatment were recorded in three categories: (1) TIA and amaurosis fugax which resolved within 24 h; (2) minor stroke causing minimal neurological deficit without loss of the functional ability which resolved within 30 days and (3) major stroke defined as deficits lasting more than 30 days with changes in the lifestyle of the patient.⁶

Twenty-three of the first 24 patients were followed-up with duplex scanning and clinical examination in 1997.⁴ Thus, the present study includes all the patients from the former study with patent ICA in 1997 ($n=23$) and, in addition, patients treated successfully between 1997 and November 1999 ($n=30$). Forty-six patients (85%) participated in a clinical examination and 45 patients (83%) also underwent a colour duplex re-examination at the beginning of the year 2000. One patient was evaluated clinically only, and eight did not participate in the follow-up: one patient had died due to pancreatic cancer, two refused to participate, three were treated with CEA after CPTA because of recurrence of a symptomatic stenosis and one had an occluded ICA. In the last patient CPTA of a restenosis in the ICA one year after CEA was technically unsuccessful and the patient is presently treated medically with aspirin and dipyridamol.

Duplex scanning was performed with the patients in supine position. All examinations were performed by the same experienced physician. We used a Siemens Sonoline Elegra® ultrasound system with a 5 Mhz linear array transducer and the angle of insonation never exceeded 55°. ICA stenosis were evaluated according to the criteria of Zweibel.⁷ For a stenosis of 60–79% the reference values were a peak velocity >130 cm/sec, end-diastolic velocity >40 cm/sec, systolic velocity ratio (ICA/CCA) >1.8 and diastolic velocity ratio (ICA/CCA) >2.4 . For a stenosis of 80–99% the reference values were a peak velocity >250 cm/sec, end-diastolic

velocity >100 cm/sec, systolic velocity ratio (ICA/CCA) >3.7 and diastolic velocity ratio (ICA/CCA) >5.5 .

Statistical analysis included calculation of the restenosis-free interval by means of Kaplan–Meier survival analysis using the intention to treat principle. The two groups were compared using the Log Rank method.

Results

Early outcome (<30 days)

CPTA with or without stent, was primarily technically successful in 50 (93%) patients. Control angiography showed a minor residual stenosis ($<50\%$) in seven (13%) patients. CPTA was not technically possible in three (6%) patients because of a tight stenosis which did not allow catheterisation. Two of these later underwent CEA whereas the third was treated medically with aspirin and dipyridamole which he had not received earlier. In another patient the artery recoiled after PTA. He became symptomatic with episodes of TIA and was treated with CEA. In one patient the endovascular stent occluded on the fourth day causing transient neurologic symptoms but thereafter he became asymptomatic.

The perioperative CPTA mortality (30 days) was zero. Neurological events were recorded in ten (18%) patients during or immediately following the endovascular procedure. One patient (2%) had an episode of amaurosis fugax, and six (11%) had episodes of TIA. Two (4%) patients suffered a minor stroke and one (2%) a major stroke. In addition, six (11%) patients were treated successfully with intravenous atropin because of bradycardia during the procedure and one patient was shortly unconscious presumably due to cerebral hypoperfusion because the contralateral ICA was occluded. The rate of neurological events was similar in the initial (5 events/24 procedures) and late periods (5 events/30 procedures) after the introduction of the CPTA in our department.

Late outcome

After a median follow-up of 34 months (range 1–80 months), 40 (87%) patients were asymptomatic and six (13%) had symptoms: TIA + amaurosis fugax ($n=1$), TIA alone ($n=4$) or major stroke ($n=1$) (Table 1).

Colour duplex sonography (45 cases) revealed that

four of the symptomatic patients (9% of all examined patients) had a significant restenosis ($>70\%$) in the treated ICA while there was no restenosis in two patients. The latter two patients had a history of ischaemic heart disease with arrhythmias.

Overall, in the 45 patients who underwent colour duplex scanning we found a stenosis between 50% and 70% in 6 patients (13%), significant restenosis ($>70\%$) in ten (22%) and ICA occlusion in two patients (5%). The incidence of significant restenosis during the follow-up in patients treated with or without stent deployment was 13% and 25%, respectively. If occlusions were included the incidence rates would be 20% and 29%, respectively. Furthermore, the median follow up time in the former group was considerably shorter than in the latter (44 months vs 14 months).

All patients except three (the one who died and the two who refused to participate) were included in a Kaplan–Meier survival analysis on an intention to treat principle. This analysis revealed a restenosis-free interval of 60% after 48 months (SEE 9%) in the CPTA group. In the CPTA with stent group the shorter observation period only allowed calculation of a restenosis-free interval of after 9 months which was 79% (SEE 11%) (Fig. 1).

Discussion

CEA is considered the gold standard for treatment of ICA lesions to reduce the risk of stroke in patients with a symptomatic significant stenosis.^{2,8} With time, however, the technical improvements have increased the use of endovascular treatments of these lesions. CPTA with or without stent deployment, has been used to treat both symptomatic and asymptomatic arteriosclerotic lesions in the common carotid and ICA since 1979.⁹ The main concern with the technique has been the risk of cerebral embolic episodes.

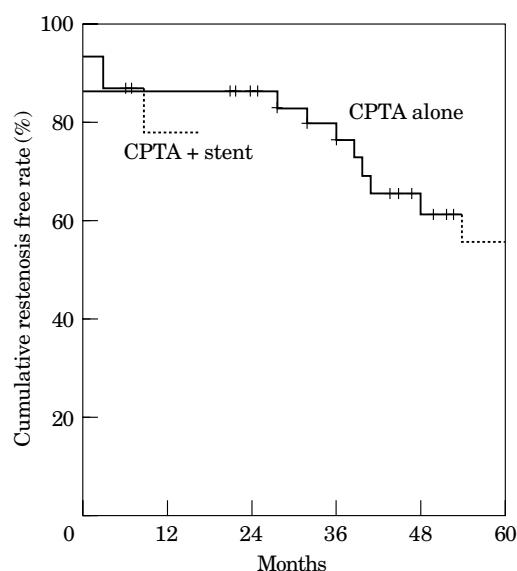
The combined incidence of mortality and major stroke from endovascular treatment of ICA lesions varies between 1–9%.^{9–14} Kritpracha and Beebe reviewed and summarised experiences of 14 non-randomised and non-controlled studies and did not draw any conclusion because many series did not provide adequate information about the patients, the indications for treatment, the complications or the follow-up time. Their short report, however, revealed that mortality and morbidity accounts for up to 30% and the risk of neurological deficits seems to be less after stent deployment compared with PTA alone.¹⁵ One of the two randomised studies so far, the CAVATAS investigation, as yet unpublished, found a

Table 1. Neurological events during follow-up (1–80 months). Forty-six patients at risk. There was a longer follow up in the group with CPTA alone. Two patients had symptoms without an ICA restenosis.

	Neurological symptoms (AF–TIA–STROKE)	No symptoms
CPTA alone (<i>n</i> = 31)	5	26
PTA + stent (<i>n</i> = 15)	1	14
Total	6	40
%	11	87

Table 2. Result of the duplex scanning at follow-up. (1–80 months, 45 patients at risk).

	Restenosis 0–70%	Restenosis >70%	Occlusion
CPTA alone (<i>n</i> = 31)	22	8	1
CPTA + stent (<i>n</i> = 14)	11	2	1
Total	33	10	2
%	73%	22%	5%



Number of patients
at risk (SE)

CPTA	31 (6%)	26 (7%)	22 (7%)	14 (9%)
CPTA + stent	14 (7%)			

Fig. 1. Calculation of the restenosis-free interval by use of Kaplan–Meier survival analysis in patients treated with CPTA alone or CPTA and stent (Intention to treat principle). All patients except three (the one who died and the two who refused to participate) were included in the analysis.

combined risk of stroke (major and minor) and death higher than 10% after angioplasty and concluded that angioplasty is as safe as surgery.^{16–18} The second randomised study from Leicester has been suspended because 5 of the 7 patients who underwent CPTA had a stroke.^{18,19}

Our results reveal a death and stroke rate (major and minor) of 5%. In comparison, the NASCET study

found a combined risk of death or major stroke of 3.1% while the risk increased to 5.8% if minor stroke was included.² The incidence of transient neurological events (TIA and amaurosis fugax), however, was considerably higher in our study than has been reported in most previous studies. One reason for this difference could be selection bias since many investigators included 40–60% asymptomatic patients with severe ICA lesions.^{13,14}

At the beginning of our study period we only used stents when the results of CPTA were sub-optimal, e.g. recoil, dissection or irregular vessel wall. We later changed our strategy, like others, and used stents more routinely.^{1,3,20} A stent may reduce the risk of microembolisation, residual stenosis and possibly also the rate of restenosis.^{1,3,14,20–22} The procedural time duration of stent placement is short and consequently the risk of cerebral ischaemia due to interruption of blood flow is reduced.⁵

Various types of stents have been used in the ICA. We used the balloon expandable Palmaz stent (Johnson & Johnson®) in the early phase of the treatment period and only the self expandable Easy Wallstent (Schneider®) for the last years. The thermosensitive self expandable nitinol stents are the preferred stents by interventional radiologists in other vascular territories.^{9,11,14,23} These stents are flexible, have a low thrombogenicity, a tight mesh and are transparent. The Palmaz stent is made from stainless steel. Because it is rigid and needs dilatation from a balloon it may result in microembolisation.⁹ Deformation of the Palmaz stent from external compression has been described in the literature with an incidence of stent collapse between 1% and 16%.^{9,11,14,23} Therefore, we do not use it any more.

Although attempts with protection balloons and filters have been introduced to reduce the risk of microembolisation to the brain during CPTA, we do not yet take such precautions. Whether these precautions will reduce the incidence of neurological complications following endovascular treatment remains to be investigated. In any case, such treatment necessitates that a guidewire and an occlusion balloon or filter is placed through the stenosis which in itself may result in emboli.²⁴ Furthermore, the occlusion balloon, while inflated, causes a prolonged period of decreased cerebral perfusion.

We catheterised all our patients through the femoral artery. Other approaches include the brachial artery or direct puncture of the common carotid artery.^{13,14,22,25} The latter procedure, however, may result in haematoma which needs surgical intervention.^{14,22}

The incidence of restenosis in the ICA after CEA varies between 15–37% after 7 years.^{24,26} However, only 1–8% are symptomatic and need re-intervention.^{21,24,26} Our results showed that 22% of our controlled patients presented with a significant restenosis greater than 70% after a median follow-up of 34 months. In addition, duplex scanning revealed an asymptomatic moderate stenosis in the treated ICA in ten patients (13%). However, only four patients (9%) presented with symptoms which needed treatment. We found no significant difference in the rate of restenosis in patients who were treated with and without stent implantation (13% versus 25% of patients, respectively, and 20% vs 29% if occlusions were included). In other respects, our results are notably different from those of many previous studies. Kachel *et al.*¹³ did not report any restenosis by duplex-scan in 69 patients treated with PTA at 6 year follow-up. Similar results have not yet been reproduced. Jordan¹² and Yadav¹¹ reported a restenosis rate after 6 months of 4.7% and 4.9%, respectively, whereas Henry *et al.*¹⁴ found restenosis in 2.3 % of 173 patients one year after PTA and stent implantation. The authors of these studies did not clearly define and specify the term “restenosis”.

Routine follow-up with duplex scanning has increased the reported incidence rate of restenosis after CEA.²⁶ However, an early restenosis which is often seen on duplex scanning the first few months after CEA remains stable and may even regress spontaneously.²⁶ The rate of restenosis may also be overestimated because duplex scanning is highly observer dependent. Systematic angiographic follow-up, however, is not ethically acceptable because of an up to 2% risk of stroke from the angiography procedure.²⁶

In conclusion, the combined mortality and risk of major stroke after CPTA was low in our series and

comparable with previous published results. Still, the rate of transient neurological events was high and the incidence of restenosis was higher than has been reported previously. Despite the advantages of CPTA and the fact that CPTA is less invasive than surgery there are still doubts regarding its safety and efficiency. CPTA remains an experimental treatment and one must clarify the indications of its use if we will offer patients with severe symptomatic stenosis of the ICA a treatment which is as safe as CEA.

References

- 1 GAINES PA. The endovascular management of symptomatic atherosclerotic carotid disease. *Eur J Vasc Endovasc Surg* 1998; **16**: 94–97.
- 2 NORTH AMERICAN SYMPTOMATIC CAROTID ENDARTERECTOMY TRIAL COLLABORATORS. Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. *N Engl J Med* 1991; **325**: 445–453.
- 3 MATHIAS K, JAEGER H, KEMPES U *et al.* Stent placement in the complex internal carotid artery lesions. *Eur Radiol* 1995; **5**: 5–79.
- 4 ABRAHAMSEN J, RØDER OC, JUSTESSEN P, ENEVOLDSEN E. Percutaneous transluminal angioplasty in selected patients with severe carotid artery stenoses: the results of a consecutive series of 24 patients. *Eur J Vasc Endovasc Surg* 1998; **16**: 438–442.
- 5 ANDERSEN PE, JUSTESSEN P, ELLE B, RØDER OC. Carotid artery stenting. *J Intervent Radiol* 1998; **13**: 71–76.
- 6 THERON J, COURTHEOUX P, ALACHKAR F, BOUVARD G, MAIZA D. New triple coaxial catheter system for carotid angioplasty with cerebral protection. *Am J Neuroradiol* 1990; **11**: 869–874.
- 7 ZWIEBEL WJ. Cerebrovascular Doppler Applications, Clinical Applications of Doppler Ultrasound. Taylor KJW, Burns PN, Wells PNT, eds. New York, Raven Press, 1995, 109–131.
- 8 ZARINS CK. Carotid endarterectomy: the gold standard. *J Endovasc Surg* 1996; **3**: 10–15.
- 9 MATHIAS KD. Angioplasty and stenting for carotid lesions: an argument for. *Adv Surg* 1999; **32**: 225–243.
- 10 ROUBIN GS. The status of carotid stenting. *Am J Neuroradiol* 1999; **20**: 1378–1381.
- 11 YADAV JS, ROUBIN GS, IYER S, VITEK J, KING P, JORDAN WD, FISHER WS. Elective stenting of the extracranial carotid arteries. *Circulation* 1997; **95**: 376–381.
- 12 JORDAN WD, JR, SCHROEDER PT, FISHER WS, McDOWELL HA. A comparison of angioplasty with stenting versus endarterectomy for the treatment of carotid artery stenosis. *Ann Vasc Surg* 1997; **11**: 2–8.
- 13 KACHEL R. Results of balloon angioplasty in the carotid arteries. *J Endovasc Surg* 1996; **3**: 22–30.
- 14 HENRY M, AMOR M, MASSON I, HENRY I, TZVETANOV K, CHATI Z, KHANNA N. Angioplasty and stenting of the extracranial carotid arteries. *J Endovasc Surg* 1998; **5**: 293–304.
- 15 KRITPRACHA B, BEEBE HG. Carotid artery stenosis: treatment by angioplasty with or without stent. *Ann Vasc Surg* 1998; **12**: 621–624.
- 16 BELL PR. Open surgery has not had its days. Vascular and endovascular opportunities. Greenhalgh RM, Powell JT, Mitchell AW, eds. London, WB Saunders, 2000.
- 17 BROWN MM. Results of the carotid and vertebral artery transluminal angioplasty study. *Br J Surg* 1999; **86**: 710–711.
- 18 BROWN, CF. Percutaneous transluminal angioplasty and stenting for carotid artery stenosis. The Cochrane Library, Issue 2, 2001.
- 19 NAYLOR AR, BOLIA A, ABBOTT RJ *et al.* Randomized study of carotid angioplasty and stenting versus carotid endarterectomy: a stopped trial. *J Vasc Surg* 1998; **28**: 326–334.

- 20 BETTMAN MA, KATZEN B, VHSNANT J *et al.* Carotid stenting and angioplasty: A statement for healthcare professionals from the councils on cardiovascular radiology, stroke, cardiovascular surgery, epidemiology and prevention, and clinical cardiology, American Heart Association. *J Vasc Intervent Radiol* 1998; **9**: 3–5.
- 21 HOBSON RW, GOLDSTEIN JE, JAMIL Z *et al.* Carotid restenosis: operative and endovascular management. *J Vasc Surg* 1999; **29**: 228–235.
- 22 THERON JG, PAYELLE GG, COSKUN O, HUET HF, GUIMARAENS L. Carotid artery stenosis: treatment with protected balloon angioplasty and stent placement. *Radiology* 1996; **201**: 627–636.
- 23 GUL YA, MORGAN RA, CHESHIRE NJ. Angioplasty and stenting for atherosclerotic carotid artery disease. *Ann R Coll Surg Engl* 1999; **81**: 90–93.
- 24 YAO JS. Angioplasty and stenting for carotid lesions: an argument against. *Adv Surg* 1999; **32**: 245–254.
- 25 DIETRICH EB, NDIAYE M, REID DB. Stenting in the carotid artery: initial experience in 110 patients. *J Endovasc Surg* 1996; **3**: 42–62.
- 26 LATTIMER CR, BURNAND KG. Recurrent carotid stenosis after carotid endarterectomy. *Br J Surg* 1997; **84**: 1206–1219.

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